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Design of intelligent distance relay for cascaded transmission lines fault detection based on fuzzy logic system

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ABSTRACT

This paper present design and Matlab simulation of intelligent distance relay based on fuzzy logic system for cascaded transmission lines with different fault places and fault conditions. To overcome the sensors problems the proposed protection relay was designed with a smaller number of current and voltage sensors, they existing only at beginning of the power system grid. The relay tested with various fault positions and fault types and the results show the suggested relay still work proficiently at all fault situations.

Keywords: Fault, Fuzzy, Electric Power system, Voltage sensor, Artificial intelligence

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1. Introduction

Electric Power system (EPS) is non-linear, complex, and highly interconnected networks which used to supply high quality and reliable electrical energy to customers [1-3]. It has numerous elements such as generators, transformers, transmission lines, circuit breakers and loads. Transmission line considered one of the main parts of the EPS networks. However, Overhead Transmission line is more prone to the fault than the other parts [4, 5].

Protection of power system is the arrangement that should place to protect the electrical system from the faults that may happen and make the system below the critical situation. This system has to keep the Electrical Power System stable, continuous and efficient by reducing the effect of the faults to the lowest property. The protection system must reduce the fault's effects (inner and outer) to the lower possible limit and keep the electrical power system works properly below and after the fault take place[6-9]. The protection of transmission line is important because it can be affected by the environment failure. So, in the design of the transmission line must take into account all possible changes that may cause any abnormal behavior.

One of most significant type of protection practical to the transmission line is the distance protection. From of voltage and current signals the distance relay system is trying to extracts the fundamental frequency phasors. Then through the computation of certain nonlinear ratio of voltage and current, the ostensible impedance grasped by the relay is obtained and compared to the predetermined thresholds[10-13]. The relay will assume that a fault occurred if the impedance falls into the protected area and it disconnect the faulted line through sending a trip signal to the faulted transmission line circuit breaker. After the relay is installed in the scheme, the most important task is to determine the thresholds (settings). The situations are attained by comprehensive short-circuit system readings in a predefined system operating condition.

Recently, artificial intelligence approaches are commonly passed in in protection system like fuzzy and neural fuzzy [14-18]. This is useful to increase the relay sensitivity and accuracy against deferent fault types and situations. In this paper, an intelligent distance relay was design and simulated based on fuzzy logic system for cascaded transmission lines with various fault types and locations.

2. Suggested power system

The proposed power system in this paper consists of three phase generation system modeled as three phase source (GS), three cascaded connection transmission lines (TL), four transformers, three circuit breakers (CB), three multi-type fault (F), and three-phase series resistance inductance capacitance (RLC) load as existing in Figure 1 below:

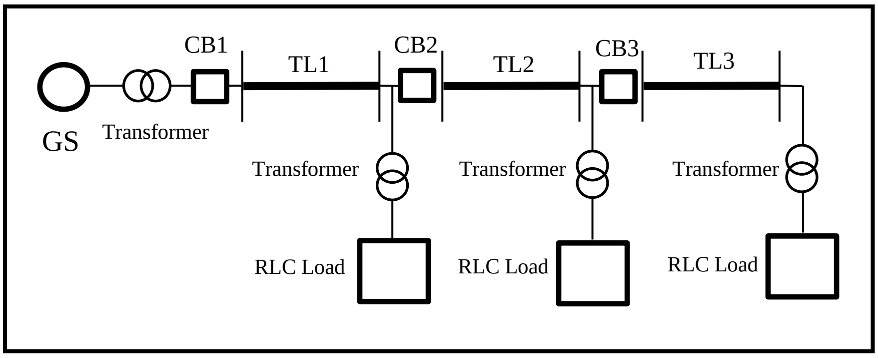

Figure 1. Suggested power transmission system with three cascaded lines

Table 1. gives the specification of the proposed power system elements as given below:

Table 1. power system elements specification

Elements	**Rating**
Three phase source	Phase to phase voltage = 11 kV, 60 Hz
Transmission lines	Line length = 100Km [RL1, RL0] = [0.1273 0.3864] Ω/km [LL1, LL0] = [0.9337e-3 4.1264e-3] H/km [CL1, CL0] = [12.74e-9 7.751e-9] F/km
Transformers	Nominal power and frequency = [250e6 VA , 60 Hz] Winging 1 parameters V1 Phase to phase= 11e3 V , R1=0.002 Ω, L1=0.08 H Winging 2 parameters V2 Phase to phase= 100e3V , R2=0.002 Ω, L2=0.08H
Circuit breakers	Breaker resistance Ron = 0.001 Ω
Multi-type faults	Fault resistance Ron = 0.001 Ω Ground resistance Rg = 0.001 Ω
Three-phase series RLC load	Nominal Phase to phase voltage=11 kV, 60Hz Active power = 10e3 W

The suggested power system distribution network was modeled with Matlab/Simulink software and it Matlab simulation is exposed in Figure 2 below:

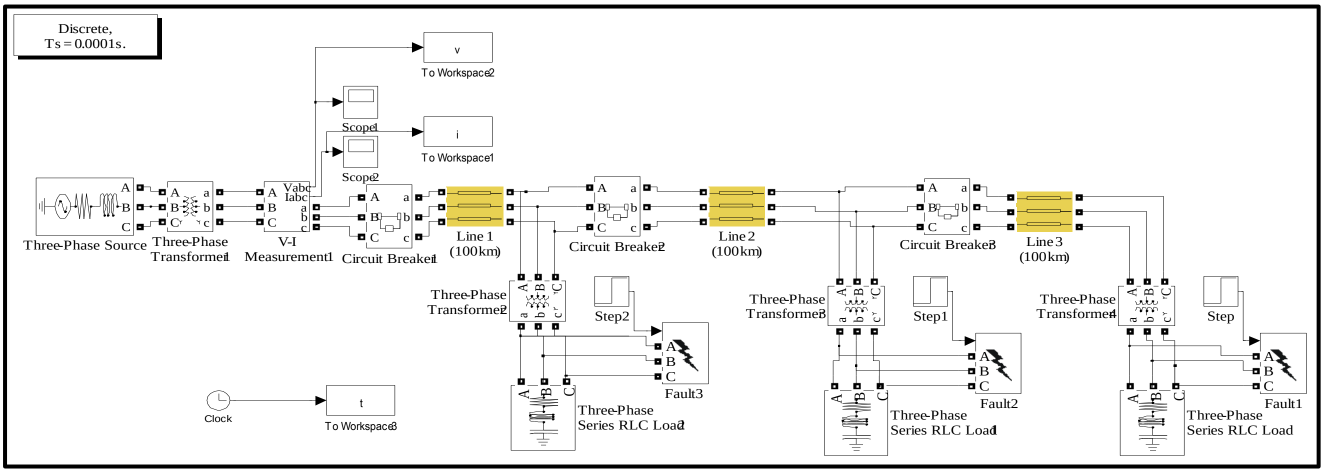

Figure 2. Proposed power system model Matlab simulation

The model was tested by applying three phase fault at different three time interval and three locations, Figure 3 and Figure 4 show the simulation model three phase voltages and currents in advance the transmission line-1 when three phase fault applied at (t=1 sec) at the end of transmission line-3 and three phase fault applied at (t=1.5 sec) at the end of transmission line-2 and three phase fault applied at (t=2 sec) at the end of transmission line-1. As affected to three phase faults the system three phase voltage decreases extremely from its standard rate as shows Figure 3. In another hand the current substantial rise due the same condition as given in Figure 4 causing damage in the power system elements.

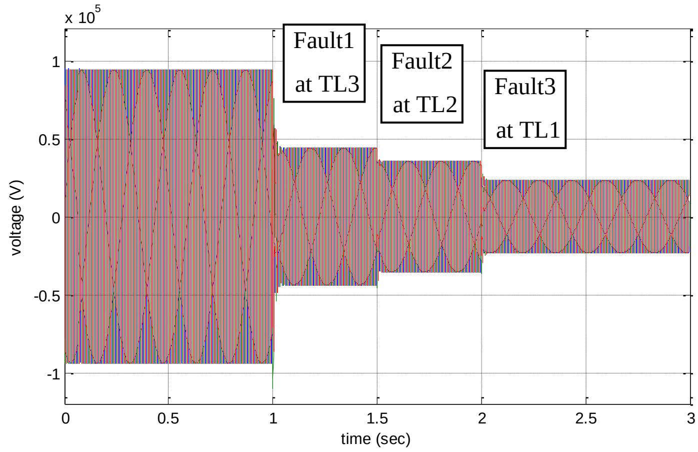

Figure 3. The profile of the three phase system voltage under cascaded faults positions

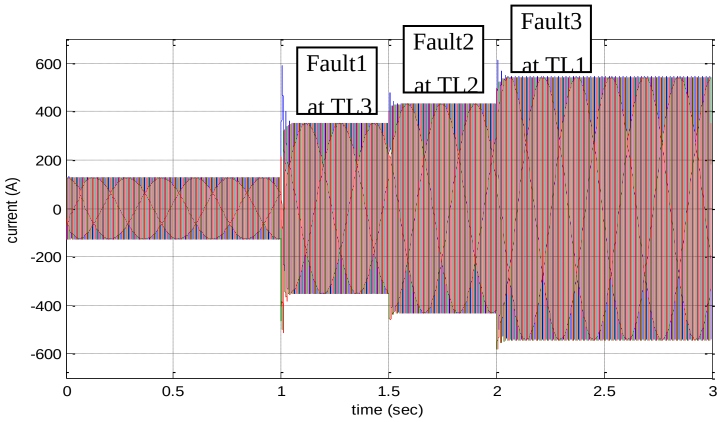

Figure 4. The profile of three phase system current under cascaded faults positions

3. Propsed distance protection

The proposed distance relay based on fuzzy logic system and it coverage to protect distributed power system with three cascaded transmission lines. The employment of fuzzy logic based with suggested distance relay on the power system model is given in Figure 5.

The relay voltages and currents input were drawn from one point only at the beginning of the distribution system as shown in Figure 5. The relay has very widely protection zone extend to all power system. Thus the relay output has three protection signals which connected to three circuit breakers distributed along the system.

Many matching steps necessary in the distance relay to implement the fuzzy logic system as exposed in Figure 6 which gives the internal structure of the planned fuzzy logic based distance relay. The first step is converting the three phase voltages and currents to the root mean square RMS values, the second step take the average value of the RMS voltages and currents, and third step converting the fuzzy logic system output to logic signals since the CBs operate by external logic signal where it closed in logic 1 and open in logic 0.

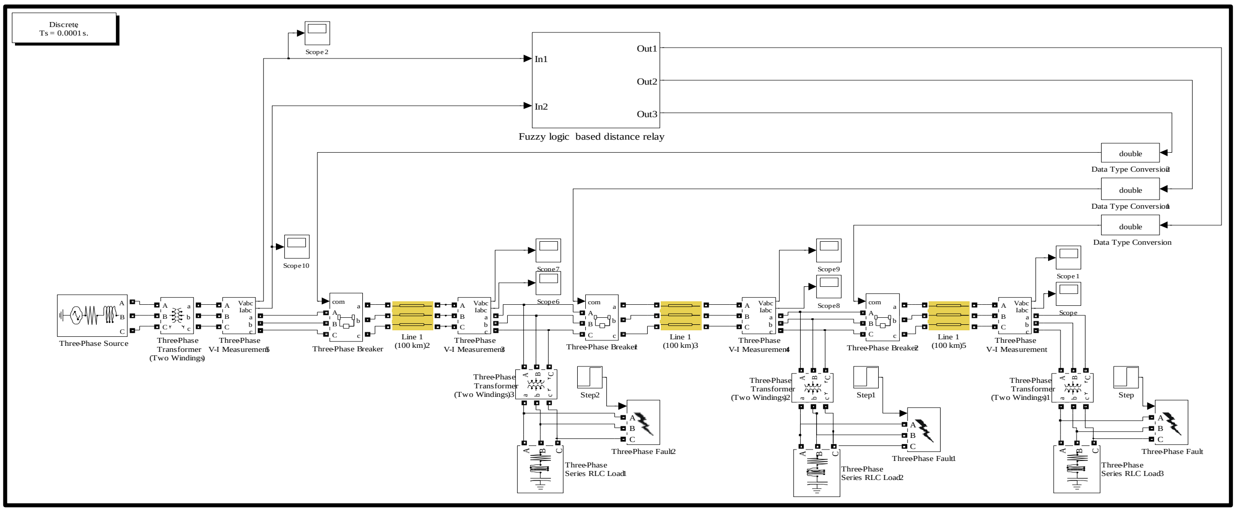

Figure 5. Implementation of fuzzy based distance relay on the suggested power system model

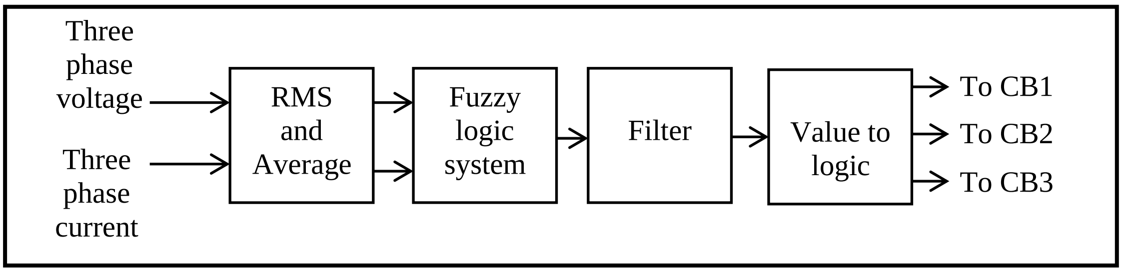

Figure 6. Structure of the proposed distance relay

The Matlab simulation of the absorbed distance relay with fuzzy logic system is given in Figure 7 below:

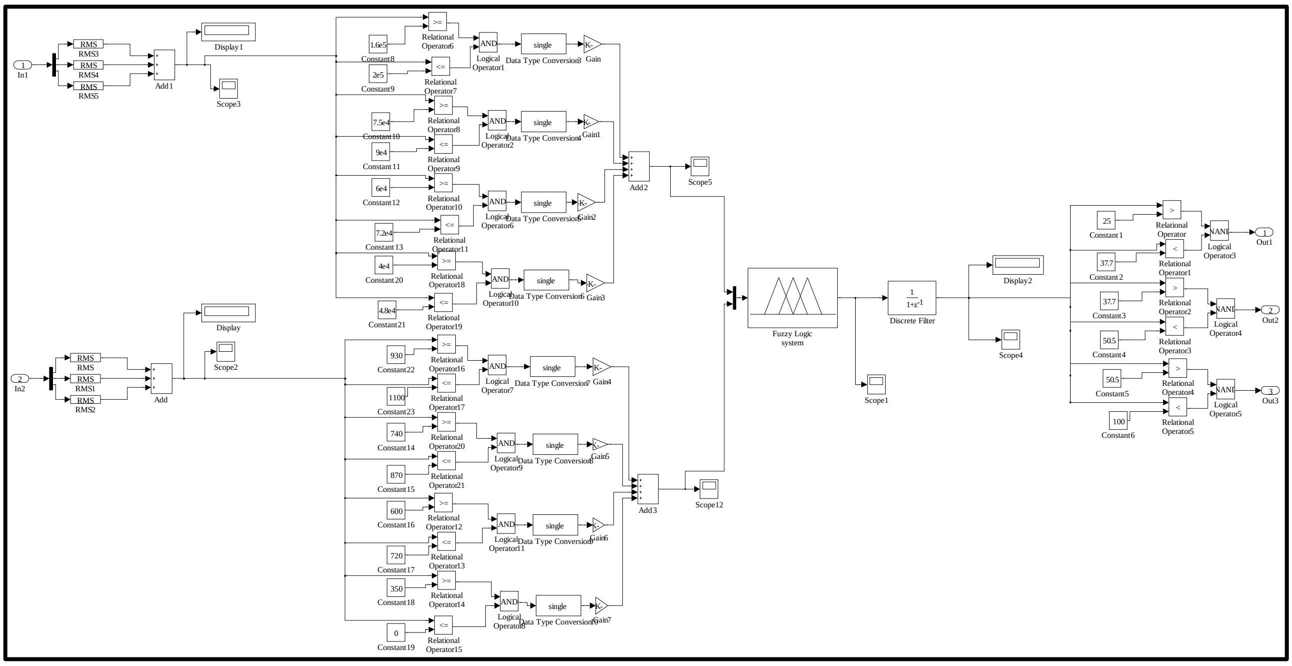

Figure 7. Matlab simulation of the absorbed distance relay

4. Design of fuzzy logic system for distance relay

The fuzzy system was built by using Matlab fuzzy editor with mamdani type. The fuzzification stage has two input variables represent the average of the RMS voltage and current. In this paper, the membership functions are taken for inputs and output are triangular forms as displayed in Figure 8 and Figure 9 with each own universes of discourse size and number fuzzy sets.

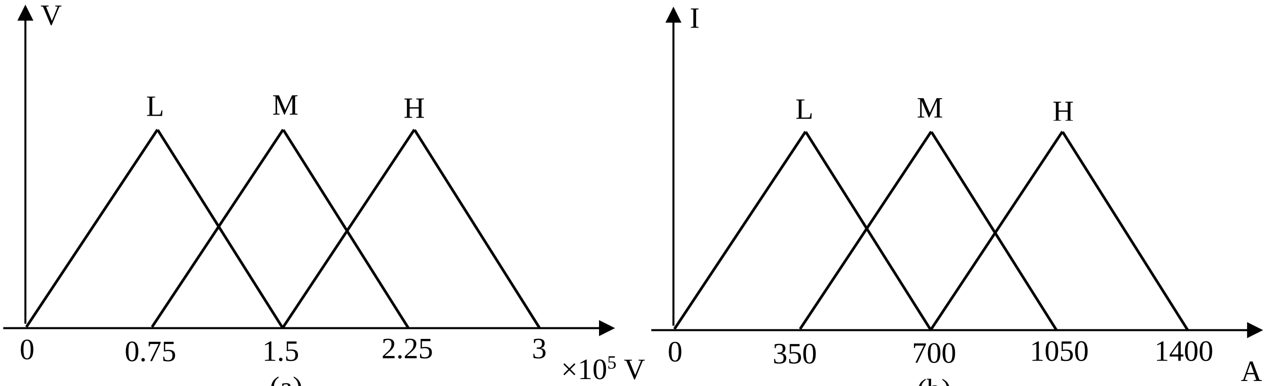

Figure 8. The input membership functions of the fuzzy system.
(a) RMS voltage. (b) RMS Current.

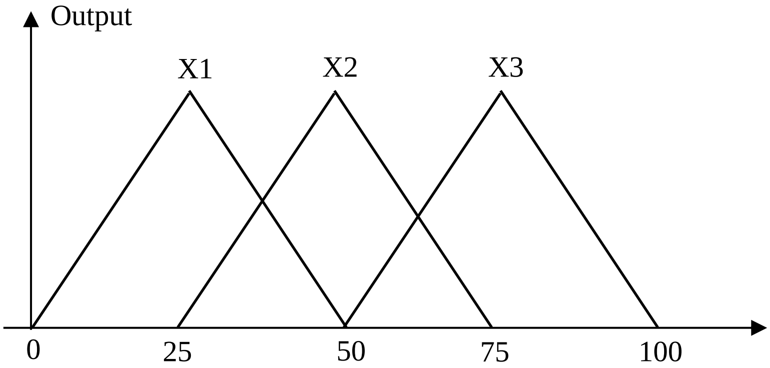

Figure 9. The output membership function.

The Rule statements were constructed automatically by the rule Editor. The voltage and current are processed by the inference engine that has to execute 9 rules (3*3) as shown in Table (2).

Table (2) Rules of the fuzzy logic system.

I \ V	**L**	**M**	**H**
L	**X1**	**X2**	**X3**
M	**X2**	**X2**	**X2**
H	**X1**	**X2**	**X1**

The rules surface extracted from the fuzzy editor was given in Figure 10 below:

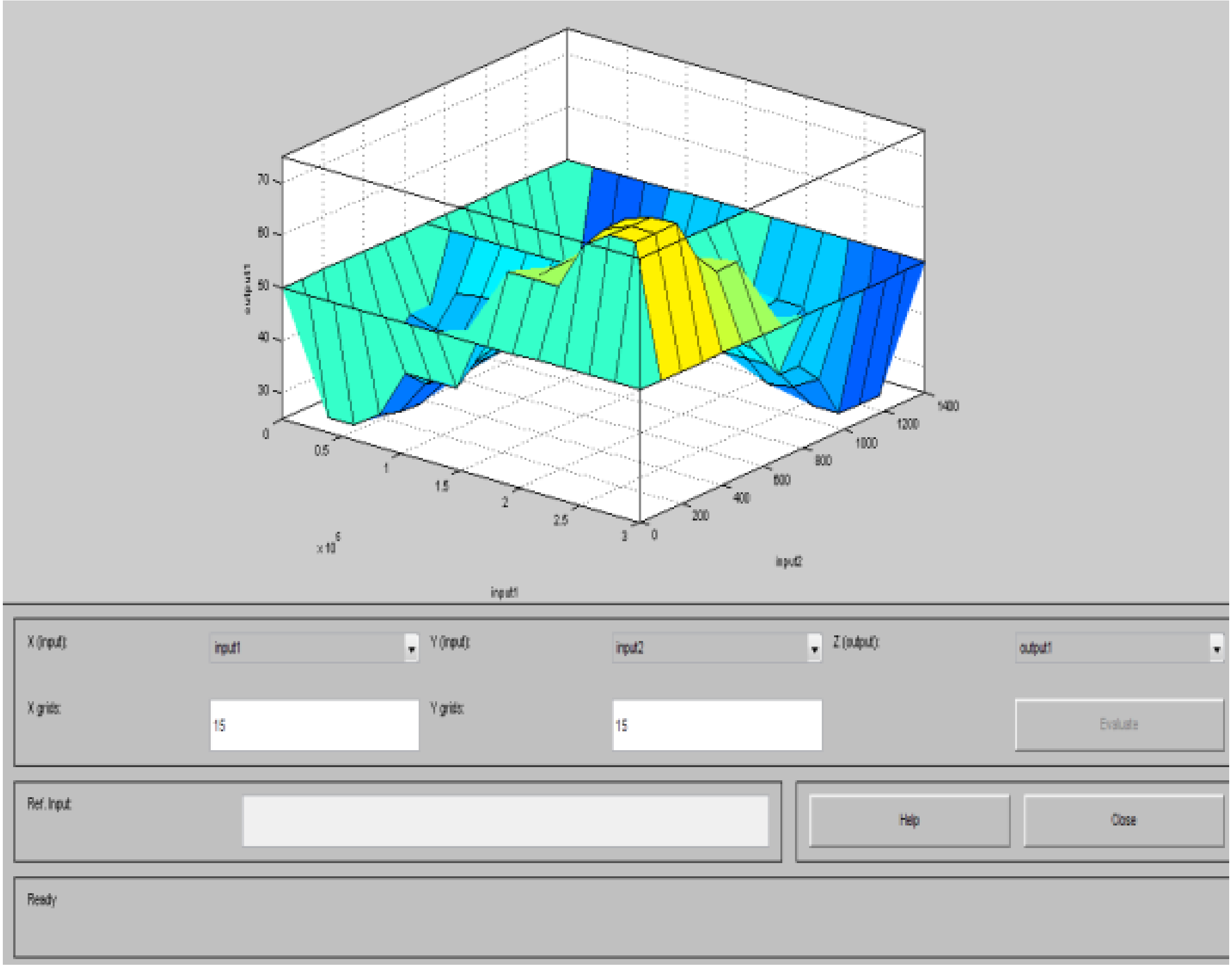

Figure 10. Rules surface of the fuzzy system

5. Proposed protection system simulation results

The protection system tested with the same fault condition as given in Figs.3&4. The simulation profiles of summation the RMS voltages and currents at fuzzy system inputs without protection system are exposed in Figure 11 below:

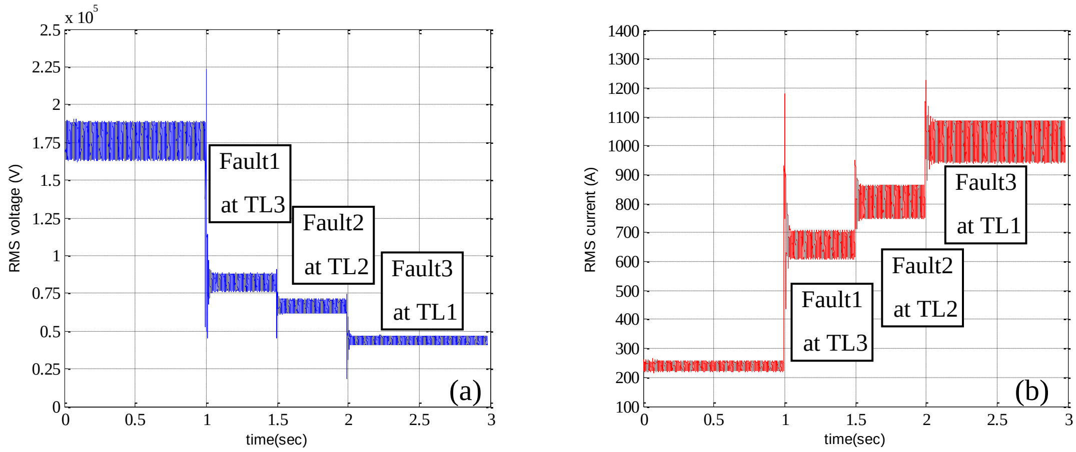

Figure 11. Summation of the RMS voltages and currents at fuzzy system inputs due to three phase faults in three different locations without protection system. (a) RMS voltages. (b) RMS currents

After the proposed protection system employed in the distributed power system it tested with various fault types to verify the protection system ability to isolate the faulted part and avoid the damage in the other elements. The fists test done by applying three cascaded three phase fault at the end of TL3 to TL1 with three time instants (t = 1 sec, 1.5 sec, 2 sec). Figure 12 shows the fuzzy protection system final output logic signals due to these fault conditions.

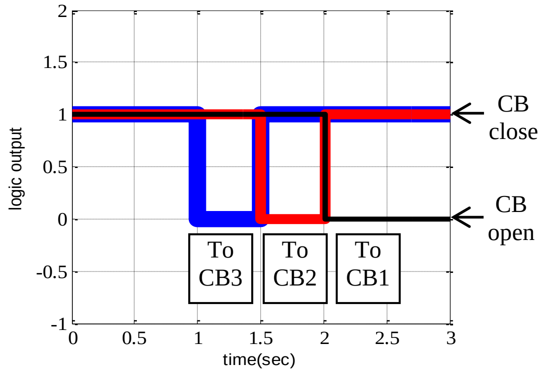

Figure 12. Final logic signal outputs of the fuzzy protection system due the present fault conditions

Figs.13&14 mentions the power system three phase voltage and current in advance the transmission line-1 when employed the proposed distance relay:

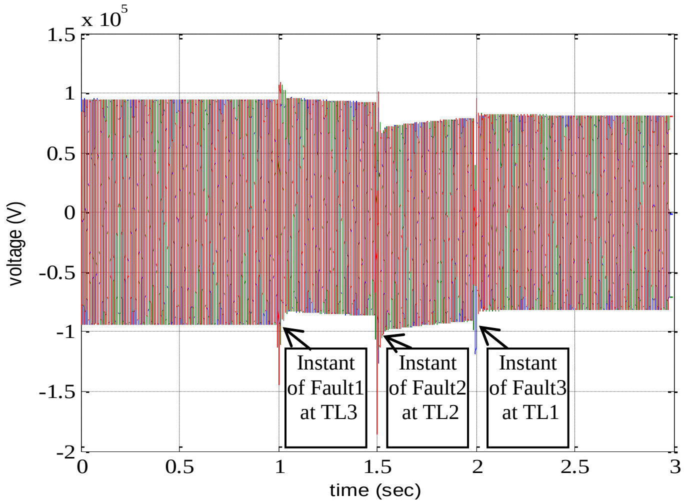

Figure 13. Three phase voltage after involving the proposed relay

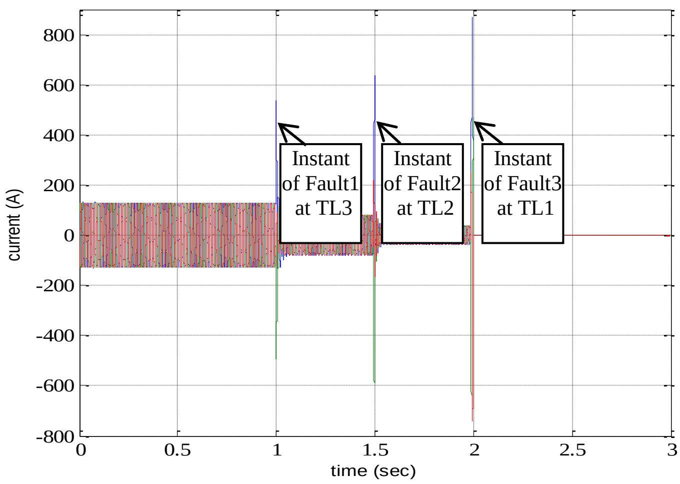

Figure 14. Three phase current after involving the proposed relay

From Figure 13 the proposed distance relay work efficiently because the distributed power system three phase voltage returned rapidly to its rated value after the 3 faults applied, and Figure 14 show the power system current fast reduce after the fault because the distance relay quickly signaled the appropriate CB to isolate the faulted parts.
The second test on the proposed relay was done by applying various fault type such as phase to phase fault (between phase-a and phase-b) on TL3 at (t = 1 sec), then fault like phase to ground (phase-c to ground) on TL2 at (t = 1.5 sec), and three phase fault on TL1 at (t = 2 sec). The power system voltage and current profiles shows the relay still works robustly when applied various fault types and conditions as shown in Figure 15&16. In Figure 16 the current will reduce gradually after very small time period when the instant of fault applied because the proposed relay isolates as fast as the faulted transmission line with its associated load.

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